CONFIDENTIAL
SECURITY INFORMATION

WOODS HOLE OCEANOGRAPHIC INSTITUTION

WOODS HOLE, MASSACHUSETTS

CONFIDENTIAL
SECURITY INFORMATION

NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794. THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

Reference No. 53-46

SONAR RESEARCH

conducted during the period

January 1, 1953 - March 31, 1953

PART I

Quarterly Progress Report
Submitted to the Bureau of Ships
Under Contract NObsr-43270 (NE 120221, Task 2)

June 1953

APPROVED FOR DISTRIBUTION ______________________
Director

Contract NObsr-43270 provides that the Contractor (WHOI) should conduct:

(i) studies and experimental investigations in connection with the structure of the ocean (including harbors and coastal waters) with particular reference to the effects of such structure on sound transmission and other aspects of submarine warfare;

(ii) analysis of data, preparation of manuscripts and training of personnel in connection with (i) above;

(iii) development, modification and construction of equipment and measuring apparatus in connection with (i) above;

(iv) consultation with Government personnel and other persons in connection with oceanographic work and equipment for apparatus for such work.

TABLE OF CONTENTS

INTRODUCTION

This is a report of activities under Contract NObsr-43270 with the Bureau of Ships during the winter quarter covering only that part of CONFIDENTIAL classification or lower. Much of the effort of the group during this period has continued to be on the deep water, long range transmission problem and is reported under higher classification. The group studying transmission participated in a 320 mile range run made by the USS SAN PABLO on a southeasterly course from the Bermuda SOFAR station during the current AMOS cruise. In addition a short combined cruise of the R/V ATLANTIS and the R/V CARYN was employed to study several specific factors affecting long range transmission in waters over the continental slope and the continental rise south of New England. Early in March the R/V ATLANTIS cruised to the Caribbean area conducting general oceanographic observations and also experimenting with techniques for studying false echo ranging targets.

The concentrated effort on sound transmission analysis during this quarter has led to experimenting with various techniques for speeding up analysis time of the explosion transmission records and for improving their use as a means of predicting steady state transmission for passive listening detection. One technique in particular has proved to be especially useful since it permits a rapid measurement of total transmitted energy. We believe this will be similarly useful in all pulse transmission studies and should be brought to the attention of groups analyzing transmission data.

The relative infrequency of cruises during the quarter has enabled the engineering group to complete production of a series of hydrophone cables with depth meters incorporated that have been developed here over the past five years. This design has received very severe testing under a wide variety of conditions and is now an excellent depth meter for general use in sound transmission studies. The depth meter is seldom dwelt upon in any detail in reports of sound transmission experiments, but it is worth pointing out that reliable measurement of the depth of a hydrophone by a convenient means that makes the information available while a test is going on, has been difficult to achieve. This development is essentially complete and an engineering report of the design is nearly ready for distribution.

Various programs such as scattering layer research and ambient noise measurements have received some attention, and significant progress has been made in the design of new instruments for underwater sound research. These activities are described below.

REPORTS

During the quarter the following reports were submitted for approval and distribution:

Reference No. 53-18, SOUND TRANSMISSION IN THE SURFACE ISOTHERMAL CHANNEL, PART II, Experimental Measurements by C. B. Officer, Jr. dtd March 1953. (Confidential)

Reference No. 53-10, THE DEEP ELECTRONIC BATHYTHERMOGRAPH by Karl E. Schleicher dtd February 1953. (Unclassified)

TRANSMISSION

Shallow Water Sound Transmission (Dr. Dietz).

On 4 February the R/V CARYN anchored at two locations in the north channel area of Boston Harbor. An ambient noise station was made at each position, and the R/V BEAR towed a Mk 4(v) acoustic noise source making two sound transmission runs of approximately 8 - 10 miles each with the R/V CARYN acting as receiving ship. Simultaneously, magnetic tape recordings were made by H. R. Johnson at the Harbor Defense Unit. (See section below.) Analysis of these data will aid in the calibration of the Deer Island system.

Two hydrophones were used at each station. An AX-120 type rested on the bottom and an AX-58 type was suspended at mid-depth. The hydrophone outputs were led into a WHOI Suitcase amplifier (WHOI Ref. No. 52-10) to be recorded on two model 311 Ampex tape recorders. The Model 311 Ampex is a two channel recorder. One channel is of the conventional amplitude modulated type; the other channel is recorded by means of a frequency modulated carrier. The f.m. system is capable of recording frequencies in the band 0 - 5000 cps.

During this cruise the a.m. channels were employed only for voice announcements. As part of the transmission runs the R/V BEAR fired one-half pound charges at five minute intervals. In addition to the tape recordings direct writing recordings were made to provide travel time data.

Participation in the Current AMOS Cruise (Dr. Hersey, Dr. Officer et al.).

As a result of discussions in meetings of the Propagation

Committee during the fall and winter the Hydrographic Office and the Underwater Sound Laboratory arranged that a series of routine transmission runs be performed using explosions as the sound source. In addition special runs were planned to be carried out in cooperation with shore based acoustic stations at Bermuda, Puerto Rico and Eleuthera, BWI. Under Contract NObsr-43270 the Institution furnished a Suitcase Amplifier with associated hydrophones, depth meters and recorders to be used on the REHOBOTH by USNUSL personnel for recording the routine runs in open water. Mr. H. R. Johnson of WHOI joined the scientific party aboard the REHOBOTH during the first leg of the cruise (Norfolk, Va. to New London, Conn.) to assist in recording the first of these runs. He later joined the REHOBOTH at Bermuda to participate in a special transmission run carried out jointly with the Bermuda SOFAR Station. For this run a party from WHOI consisting of Dr. Hersey, Dr. Officer, Dr. Dietz, Mr. Dow, Mr. Davis and Mr. Carter recorded explosion transmissions received at both the Cove Point geophone and the High Point moving coil hydrophone at Bermuda in cooperation with scientists regularly attached to the SOFAR Station.

For this run the REHOBOTH took station 320 miles southeast of Bermuda to receive shot transmissions from the SAN PABLO, which proceeded at 10 knots on a straight course from Bermuda to the REHOBOTH dropping 3 lb. TNT charges every fifteen minutes fused to explode at approximately 30 to 50 foot depth. Every hour she also dropped a charge set to detonate near the SOFAR channel axis, and towed a Mk 4(v) acoustic minesweep near Bermuda and near the REHOBOTH. It turned out to be necessary to make a choice between recording the shots or the minesweep because of the large difference in source strength. We chose to concentrate on the shot records, and hence have a considerably better record of these, although the minesweep could clearly be heard during the early part of the run.

No detailed analysis of the resulting data has been made as yet. However, both shallow and deep shots were received readily throughout the run both on Bermuda and on the REHOBOTH. Qualitatively the received intensity at both receivers on Bermuda showed considerable systematic variation as a function of range indicating either strong focal regions, or marked shadow zones, or both.

Cruise of the R/V ATLANTIS and the R/V CARYN (Dr. Hersey et al.).

From 17 to 20 February the ATLANTIS and CARYN cruised in company to the first deep water south of Woods Hole to study various factors affecting long range sound transmission. Dr. Hersey, Dr. Dietz, Mr. Bergstrom, Mr. Backus, and Mr. Carter made up the scientific party on the ATLANTIS while Dr. Officer, Mr. Johnson, and Mr. Davis made up the party on the CARYN. During most of the cruise sound transmission runs were made using small TNT charges as the sound source. The ATLANTIS, hove to, acted as receiving ship for all the runs and the CARYN dropped the charges, recording the shot instants and transmitting them by radio to the ATLANTIS. Fig. 1 shows the location of the various runs and the following table summarizes the studies carried out. All runs were basically range runs in which the CARYN commenced the run at a short distance from the ATLANTIS and continued on a straight course dropping charges at frequent intervals. During all the runs direct writing recordings were made on the ATLANTIS to

TABLE OF SOUND TRANSMISSION RUNS

Purpose	Charge Weight and Depth	Hydrophone Depths	Length of run (Yds.)
Determine short range transmission in a thick isothermal layer.	1/2 lb. TNT at 30 feet	6 to 12 & 150 to 210 ft.	10,000 (4 runs)
Determine bottom reflectivity from normal incidence out to critical angle reflection.	1/2 lb. TNT at 2 feet	8-12, 35-40 & 550-750 feet	25,000
Compare the response of various hydrophones to explosive transmissions.	1/2 lb. TNT at 30 feet	2 hyd. at 90 to 115 ft.	7,800 (12 runs)
Determine transmission from shots fired over the continental slope to a receiver in deep water.	2 lb. TNT at 30 feet	6-12, 80-90 & 550-650 ft.	83,000

determine travel times, while magnetic tape recordings were made for subsequent analysis ashore. Since the cruise several analyses of the transmission data have commenced, but they are still underway at the end of the quarter.

In addition to the sound transmission runs a few scattering layer recordings were made from shots fired from the ATLANTIS, and whenever the ATLANTIS was underway routine operation of echo ranging gear was carried out using the BQS transducer mounted in a 40 inch ball and towed by articulated chain. These latter tests were designed to test both the mechanical and electronic systems for continued

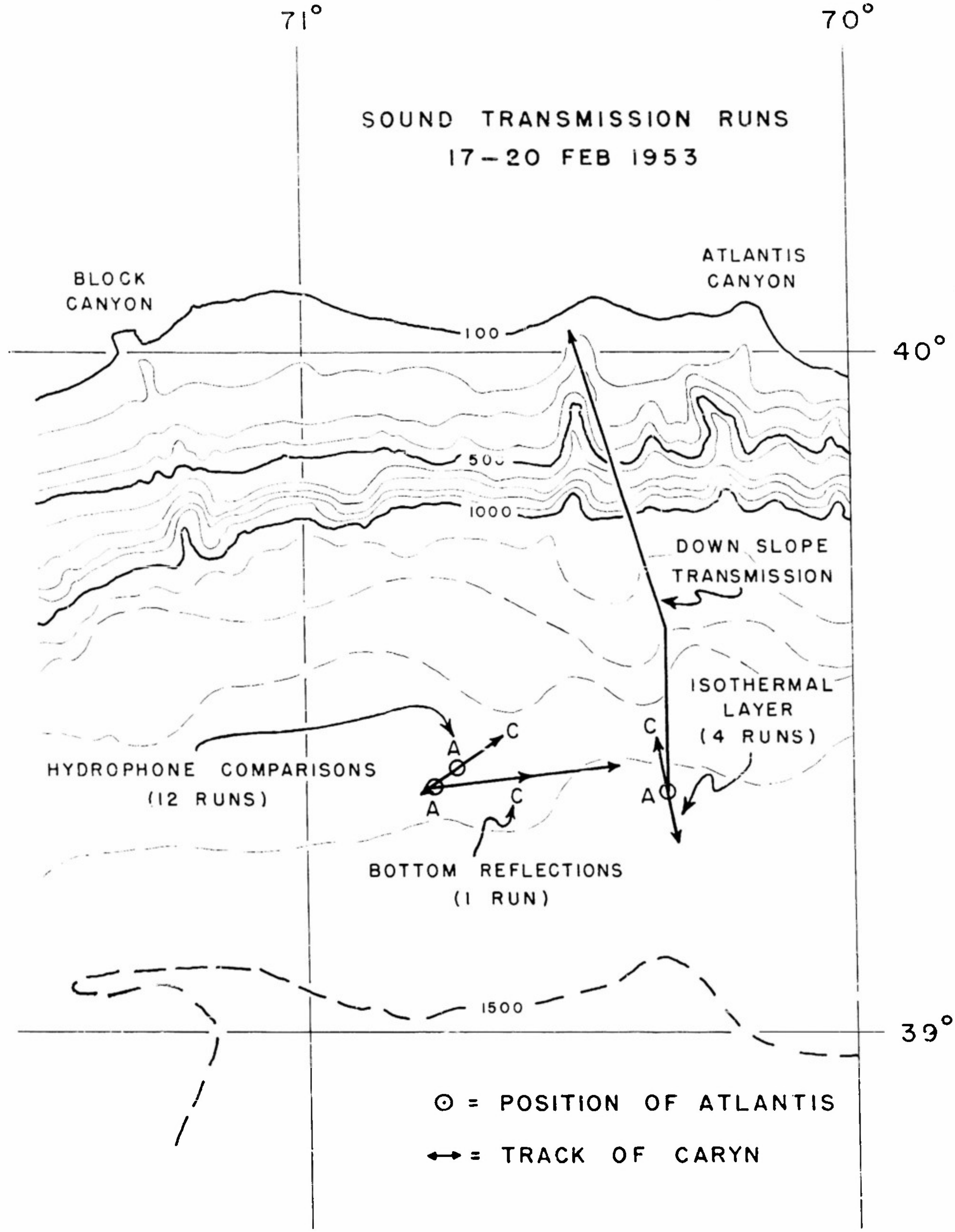

71°
70°
SOUND TRANSMISSION RUNS
17–20 FEB 1953
BLOCK CANYON
ATLANTIS CANYON
100
40°
500
1000
DOWN SLOPE TRANSMISSION
ISOTHERMAL LAYER (4 RUNS)
HYDROPHONE COMPARISONS (12 RUNS)
A
C
A
C
C
A
BOTTOM REFLECTIONS (1 RUN)
1500
39°
⊙ = POSITION OF ATLANTIS
⟷ = TRACK OF CARYN

FIG. 1

operation over many hours, and to try out various procedures for searching for false targets. The gear operated well enough to bring its various shortcomings into bold relief. They are: excessively high noise level, which was almost certainly screw and engine noise transmitted through the water to the BQS, poor paper feed of the chemical recorder, and repeated failure of a thyratron in the chemical recorder. In other respects the whole system gave little trouble even though the sea state was 4 to 5 for most of the cruise.

Several attempts were made to obtain recordings with the inverted echo sounder. However, its recorder performed poorly and could not be improved in the time available to work on it. Hence an excellent opportunity was missed to record bubble entrainment from large waves.

Total Energy Computations (Dr. Officer and Dr. Dietz).

It has often been desirable to obtain total energy of the various received signals from the results of underwater sound transmission tests using explosive sources. In the past this has been circumvented in part by plotting peak intensities or, in more careful cases, by squaring individual peaks and integrating numerically, a time consuming process of negligible interest in itself.

The statement has been made on several occasions that this should be a simple task for electronic computing components to perform. Recently such components have become available on the commercial market. Fig. 2 is a block diagram of an analysis arrangement in

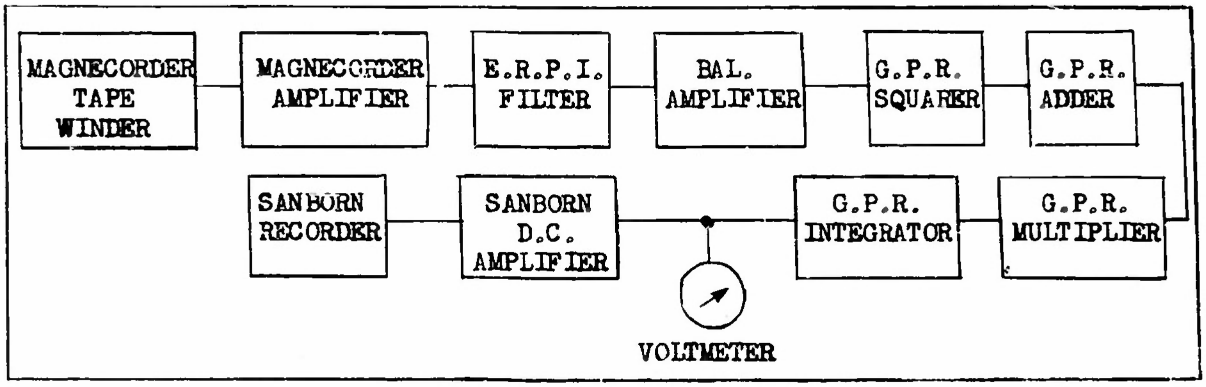


Fig. 2

operation at WHOI. The original magnetic tape recordings are played through the recorder amplifier and a filter set to the bandwidth of interest. In recent analyses an E.R.P.I. octave band pass filter has been used. The signal is amplified 20 - 30 db by an old type Ballantine amplifier-voltmeter, model 300. (Model 310A has not proved suitable for this particular purpose.) The signal is then squared, multiplied if necessary, and integrated. The purpose of the adder is to balance out any drift in the system and/or the background on the original recording. The integrated output is read on a voltmeter or recorded. The computer components are manufactured by George A. Philbrick Researches, Inc.

The system has proved to be very good. It has given consistent reproducible results, and the limits of accuracy and resolution of the computing components are well within the limits demanded by the experiments. The computing components are stable when operated from the appropriate regulated power supply. The only precaution, which is an important one, is to insure that there is no overload throughout the system from any of the signal peaks.

ECHO, REVERBERATION AND SCATTERING STUDIES

<u>Target Classification</u> (Mr. Backus).

Compilation of an annotated bibliography pertaining to the classification of submarine targets was completed during this quarter and is now ready for reproduction and distribution. This bibliography will be submitted as two reports, one being classified and the other unclassified. The classified report consists of 21 titles and contains references written as direct contributions to the solution of the target classification problem together with references on certain acoustical properties of wakes and classified references on the deep scattering layer. The unclassified report, consisting of 124 titles, contains references to the deep scattering layer and to the fishery applications of echo sounding and ranging.

The cruises initiated during the previous quarter to examine the distribution of scattering groups by means of the 12 kc echo sounder over the continental shelf and slope south of Woods Hole were continued during the present quarter. These cruises have revealed that, with respect to scattering groups, an entirely different situation exists in this area during winter months than during fall months. Scattering groups (presumably schools of fish and potential false targets) which are so abundant during fall months are practically non-existent during the winter months. Thus our echo sounder observations are in complete agreement with our general biological knowledge of the seasonal movements of pelagic fishes in this area.

A program of measuring the target strength of potential false targets was initiated during this quarter and was largely devoted to the development of procedures and to instrument trials. During cruises to these ends no false targets were contacted.

The biologist participated in Cruise 184 of the R/V ATLANTIS for the period 6 March - 31 March. This cruise, which departed from Woods Hole, operated in the area of Guantanamo Bay, Cuba. In a search for false targets the echo ranging gear was operated continuously from Woods Hole to Guantanamo Bay except for short periods and almost continuously while in the Guantanamo area. Although the echo ranging gear and associated apparatus operated extremely well with few exceptions, no false targets were encountered during these operations. This lack correlated well with the very low level of biological activity observed by other means in the areas worked during the cruise.

In cooperation with Mr. Robert A. Westervelt of the U. S. Navy Underwater Sound Laboratory, Hersey, Schevill and Backus prepared a draft of a questionnaire to be answered by sonar personnel on anti-submarine vessels. The proposed questionnaire was submitted to participants of a conference on target classification held at the Bureau of Ships on 25 February, 1953 where it was modified.

From information gathered by this questionnaire it is hoped that data on the frequency and distribution of false targets and the method of their identification as such may be accummulated.

<u>Explosive Echo Ranging</u> (Dr. Hersey and Mr. Bergstrom).

Submarine echoes from data taken in the Guantanamo area in April 1951 and south of New England (see WHOI Ref. No. 51-61 pp. 4-6) in June 1951 have been analyzed to obtain target strength values as a function of frequency and target aspect. Transmission loss corrections were based on one way transmission measurements made between a 30 foot source depth and 700 foot receiver depth at Guantanamo in a separate experiment. Both the echo ranging and direct transmission tests were carried out at ranges from 700 to 1000 yards, except for a few shots as indicated below. All tests were made in water deeper than the range of the target. Subsequent analyses indicated that all transmissions had taken place in the direct sound field and that the principal acoustic paths were direct and by a single surface reflection.

Target strengths were computed by the following steps:

1. Original magnetic tape recordings of both echo and direct transmissions were played to an endless loop recorder through the desired band pass filter, and the endless loop tapes played through the same filter to be photographed from an oscilloscope.

2. Estimates of average peak amplitude of the echoes and the direct transmission were reduced to equivalent levels re 1 dyne/cm^2.

3. Target strengths were computed by correcting the direct transmission levels to the range of the particular echo and using the formula

$$TS = E + 20 \log_{10} R - S$$

where

TS = target strength
R = target range
E = echo level re 1 dyne/cm^2
S = direct transmission level corrected to range R. (equivalent to the usual $S_o + 20 \log R$, where S_o is the source level at $R = 1$)

The source function, S, is a function of frequency both because of the properties of the explosive shock wave and also because of the transmission paths between source and target and target and receiver. The available transmission data is from a source similar to that in the echo ranging tests but a source and receiver relationship fitting only one transmission path. Therefore the resulting target strengths may well be in error, at frequencies below about 0.5 kc.

Fig. 3 shows target strengths in octave bands from 0.5 to 16 kc for runs on the USS TUSK (keel depth 200 ft.) at Guantanamo (beam to stern). These data were taken using a UQN-1 transducer (Edo Corp.) in a small VDS fish towed at about 30 foot depth from the R/V ATLANTIS. The shots were dropped by the ATLANTIS and went off within 100 to 150 feet of the receiving transducer. Similar measurements from beam to bow on the USS HALFBEAK at periscope depth in June 1951 could not be reduced to give target strength, but showed echo levels around to the bow relative to beam aspect at least as high as those of fig. 3 around to the stern.

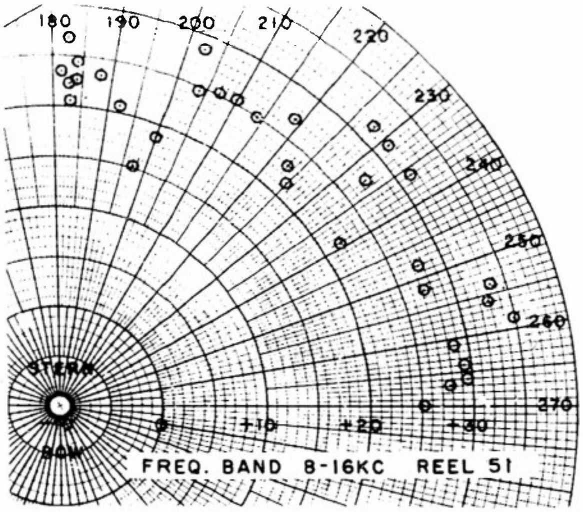
During the Guantanamo tests two runs were made in which the

USS TUSK

TARGET STRENGTH vs. ASPECT

IN OCTAVE BANDS

0.5 TO 16KC



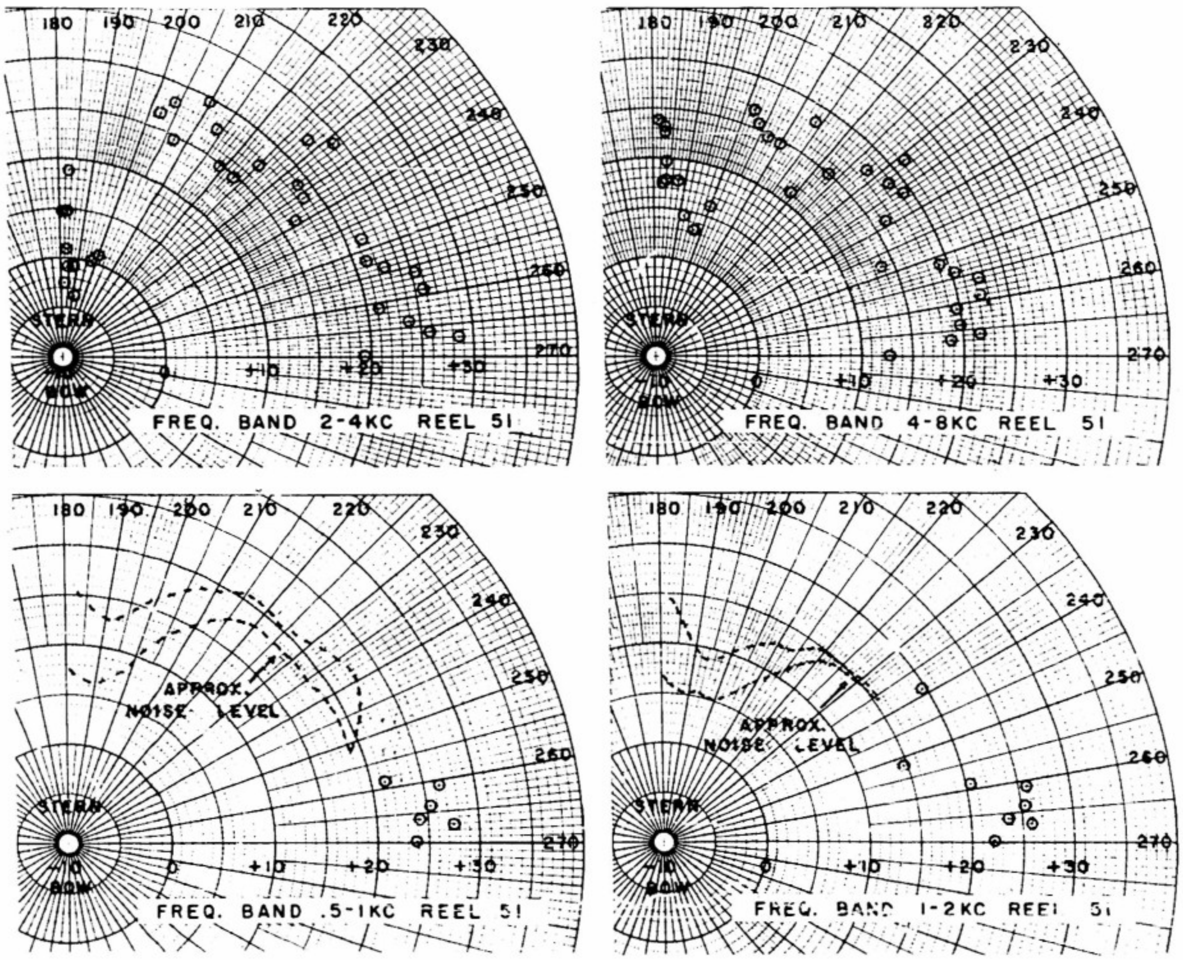


FIG.3

ATLANTIS received with an AX-58 type hydrophone at 700 foot depth while hove to and the R/V CARYN dropped the charges to go off at 30 feet. The TUSK was at periscope depth. Fig. 4 shows the tracks of the TUSK and the CARYN relative to ATLANTIS. Figs. 5 and 6 show target strengths in octave bands from 0.5 to 16 kc and in "logit" bands from 0.11 to 1.12 kc respectively for selected shots from these two runs.

The experimental VDS fish receiving shots of fig. 3 had a variable noise level caused by faulty towing gear. This interfered with the measurements at low frequency toward stern aspect. Hence, the noise level is indicated for the .5 to 1.0, and 1 to 2 kc bands showing only that target strengths do not exceed the values shown. The runs of figs. 5 and 6 were made under silent ship conditions, and the resulting low noise levels permitted low frequency measurements. Target strengths could readily be measured for all usable data from runs 1 and 2 between .5 and 16 kc; these are shown in fig. 5, which also contains source and receiver range and target aspect data. Only a few shots provided data having adequate signal-to-noise ratio for measuring target strength well below .5 kc. Some of these were analyzed through logit filters between 0.112 and 1.12 kc (see fig. 6). The apparent target strength decreases with frequency for all the shots so analyzed and these were chosen as having the most favorable signal-to-noise ratio in the low frequencies. Shot 26 is an exception. It is near beam aspect, and indicates that high target strengths may persist to lower frequencies there. Hence, it can be concluded that target strengths between 0.1 and 0.4 kc are small for the particular geometry chosen for these tests. However, since both submarine and sound source were shallow it seems probable that because of the surface image effect the sound incident on the submarine below about 0.5 kc could have been appreciably less than indicated by the transmission tests to the hydrophone at 700 feet. This would make the target strength appear too low. In the higher frequency range, above 0.5 kc, there is a marked drop in target strength below 2 kc compared with higher frequencies for both bow and stern aspects; near beam aspect there is no marked dependence of target strength on frequency above 0.5 kc.

A number of shots shown on fig. 5 have widely different source and receiver aspects. The sample of these data is too small to conclude anything except that roughly comparable target strengths are obtained whether or not the echo is received over the same path as the incident sound.

From these measurements the following tentative conclusions are drawn:

1. Target strengths at all aspects show no marked frequency dependence above about 3 kc.

2. Below about 3 kc target strengths are lower than at the higher frequencies except at beam aspect. There they appear to be

TWO SHIP EXPLOSIVE ECHO-RANGING 20 APRIL 1951
R/V CARYN (SHOOTING) R/V ATLANTIS (RECEIVING)
USS TUSK (TARGET)

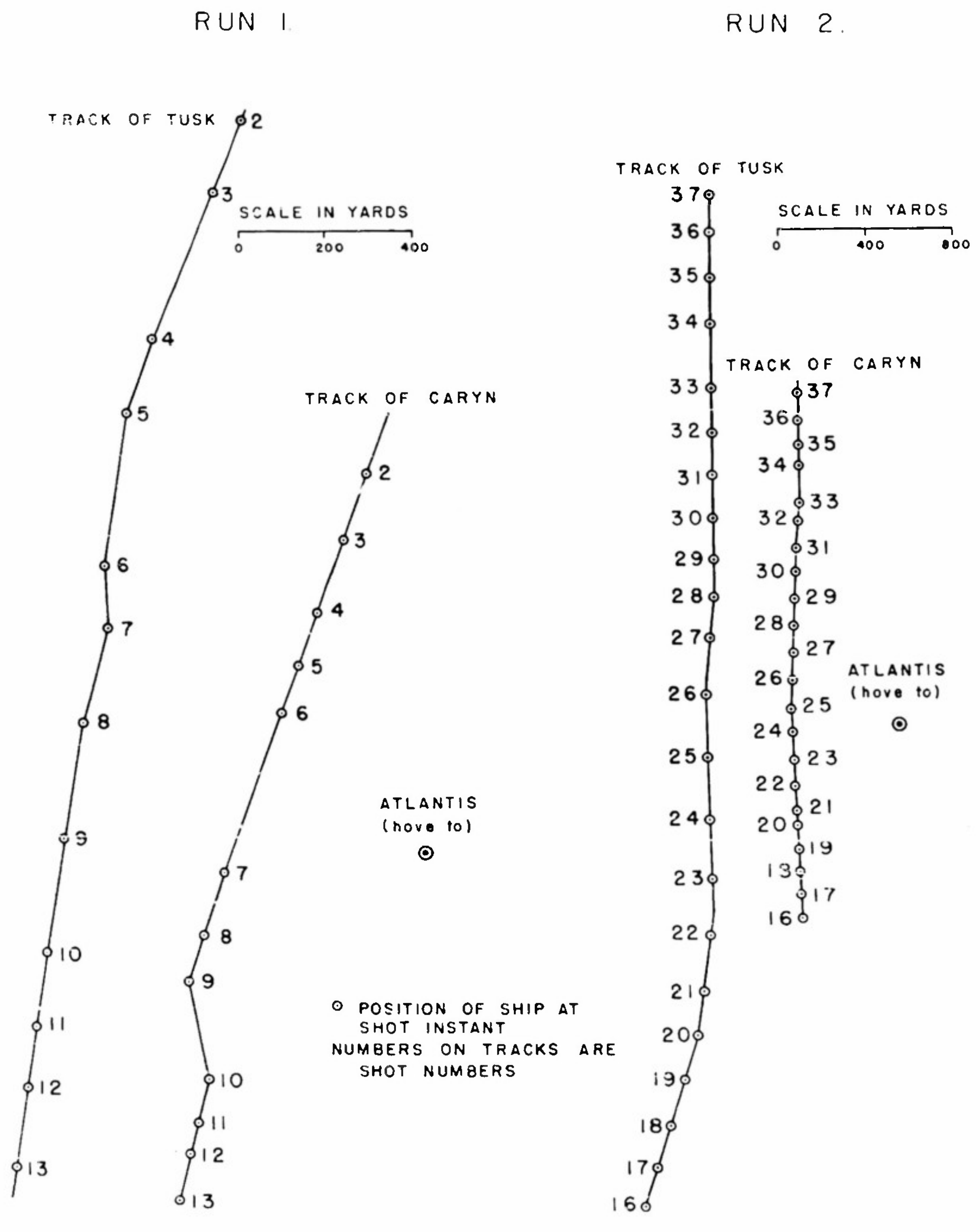
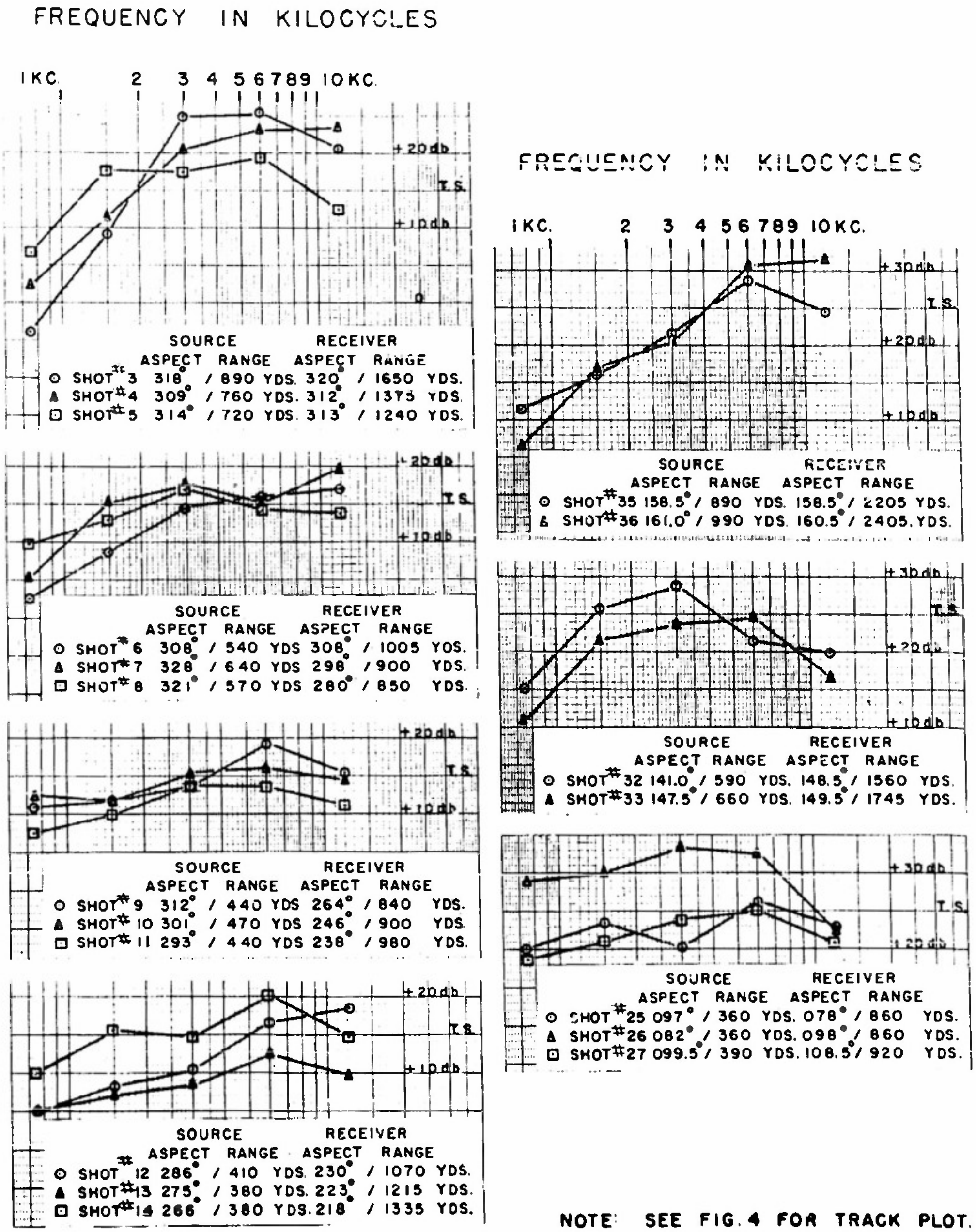


FIG. 4

USS TUSK

TARGET STRENGTH vs. FREQUENCY

IN OCTAVE BANDS 0.5-16 KC



NOTE: SEE FIG. 4 FOR TRACK PLOT.

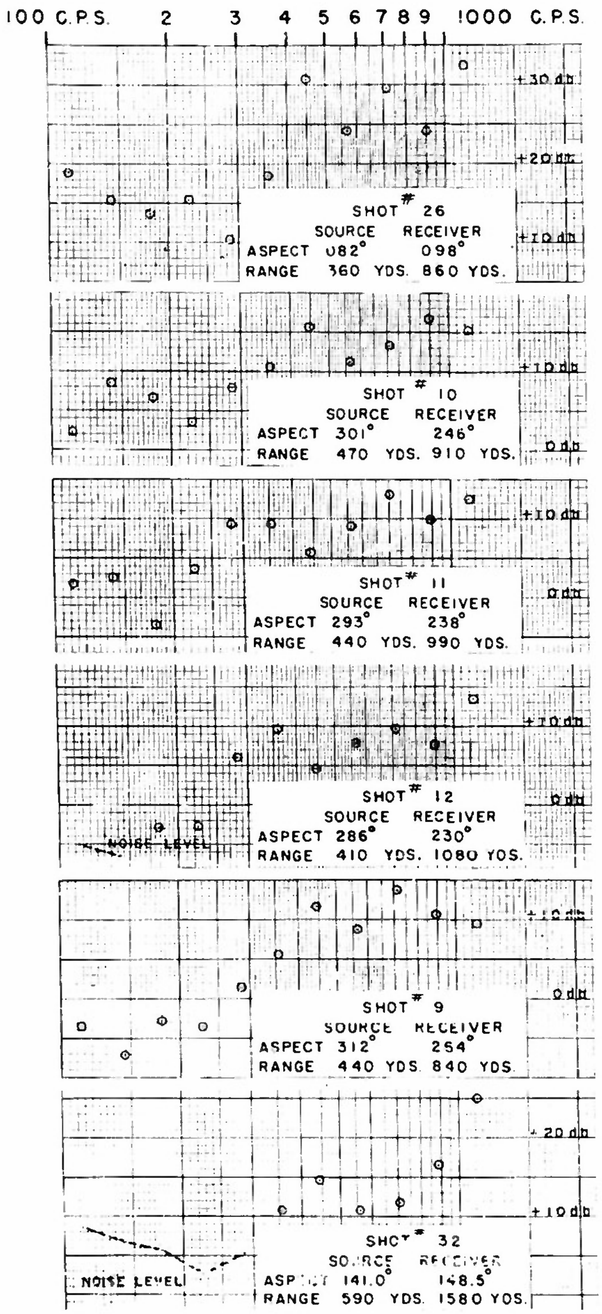
FIG. 5

CONFIDENTIAL
SECURITY INFORMATION

USS TUSK

TARGET STRENGTH vs. FREQUENCY

100 TO 1000 CYCLES PER SECOND



NOTE:
SEE FIG. 4 FOR TRACK PLOT

FIG. 6

CONFIDENTIAL
SECURITY INFORMATION

independent of frequency down to about 0.4 to 0.5 kc.

3. Below 0.4 to 0.5 kc target strengths appear to drop off sharply at all aspects. This apparent drop off may be due in part to inadequate corrections for low frequency transmission effects.

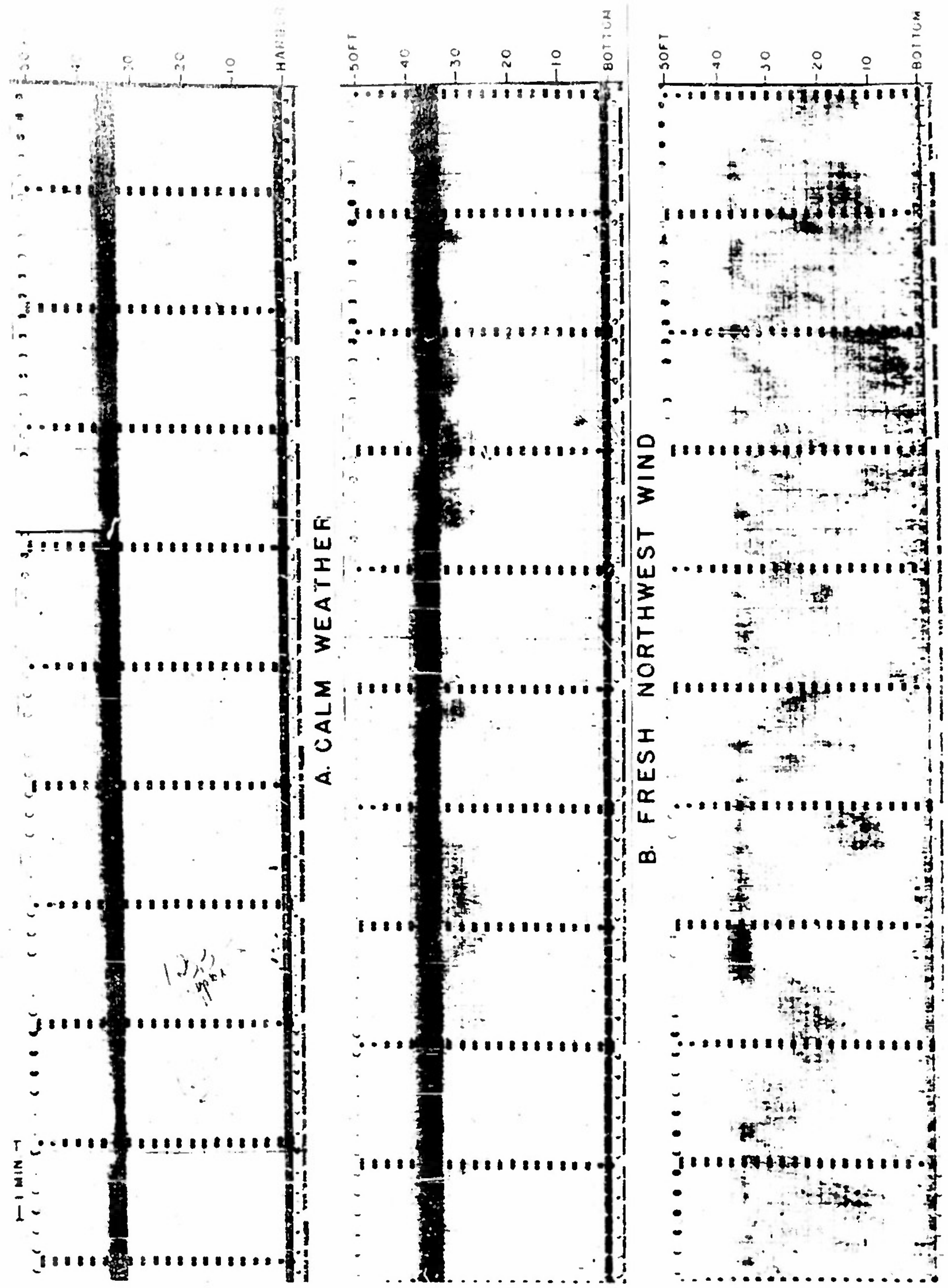
If transmission effects are controlling the apparent target strengths at low frequencies, appropriate arrangements of source and receiver may improve ability to detect low frequency echoes. This possibility obviously warrants further study.

These same data are being studied with high resolution photographic techniques to learn more about echo structure. This study has progressed little farther than the crude beginnings reported earlier in WHOI Ref. No. 51-61, pp. 5-6. Very high resolution scope photographs of some of the off-beam echoes suggest that many parts of the submarine such as the bow and stern, the ends of the pressure hull, and the conning tower reflect sound. However, there appear to be other reflecting points that are equally effective. It is evident that a considerably more detailed and more precise set of data is required to test hypotheses of echo structure. We look forward to another opportunity to continue field work on this problem. This is now scheduled for the end of next quarter with the USS SEA ROBIN (SS 407).

<u>Observations with the Inverted Echo Sounder</u> (Dr. Hersey and Mr. Backus).

The inverted echo sounder (see WHOI Ref. No. 52-101, pp. 11-13) has been used as a hovering device on a short cruise of the ATLANTIS and as a bottom-mounted device in Woods Hole harbor from time to time throughout the winter. During the ATLANTIS cruise a series of observations was taken at intervals down Vineyard sound to a point about 10 miles south of No Man's Land. There the ATLANTIS hove to and repeated recordings were taken during the first part of a winter storm. In this series waves were recorded from a short chop having amplitudes from six inches to a foot to wind driven waves from the storm having amplitudes up to 5 or 6 feet. Much the same general characteristics are to be found on these records as those taken in comparable sea states last summer by Mr. Bronk (see reference above).

The bottom-mounted transducer was located in 32 feet of water about 100 feet west of the Institution dock at Woods Hole, being intended principally as a handy testing device and only secondarily as a means of observing bubbles entrained by waves. Nevertheless several hours of recordings have been made from this transducer both during calm weather and through several winter storms. A typical calm weather recording is shown in fig. 7A. Whenever observations have been made



INVERTED ECHO SOUNDER RECORDS IN WOODS HOLE HARBOR

FIG.7

during a fresh northwesterly wind, traces of the type shown in fig. 7B are common. Evident reverberation is seen more closely related to the surface than to the bottom, appearing to move downward from the surface with time. This sort of reverberation is not observed unless there are also white caps being formed in the harbor, though not necessarily over the transducer. There are strong tidal currents in this harbor, and we believe the bubbles which we suppose to be the sound scatters may well be formed elsewhere in the harbor and carried over the transducer by the tidal currents. This view is considerably strengthened by observations taken during two southeasterly storms. A southeasterly wind has a considerably longer fetch coming into the harbor than does a northwesterly wind which blows across it. Fig. 7C shows a quite typical recording taken during a part of a southeasterly storm when the wind was blowing somewhat over 30 knots. Here the reverberating mass is so thick as to attenuate the 40 kc signal so that no surface echo is recorded at all. This failure to record the surface because of dense clouds of scatterers in the water may go on for many tens of minutes during the height of such a storm, and then as the storm abates the surface may be 'seen', at first only for short periods every two or three minutes, then with greater frequency and for longer times, and finally steadily, though reverberation still records below the surface with diminishing intensity as the wind dies away. Such a continuous recording of an abating southeasterly storm is shown in fig. 8. From visual observations it is certain that there are many entrained bubbles near the surface during such a storm, and the known strong tidal currents make it plausible that these bubbles be carried down to the bottom as indicated by the recordings. However, we cannot establish from any observations yet made what portion of the reverberation is due to bubbles and what may be caused by mud picked up from the bottom during such an intense storm. We intend to continue open water observations to determine whether storms that form many white caps have any clouds of reverberation similar to those found in the turbulent harbor waters at Woods Hole. It seems likely, for example, that observations in or near the Gulf Stream might reveal such deep mixing of intense clouds of bubbles. Thus far we have encountered no such storms when the gear was working.

<u>Scattering Layer Observations</u> (Mr. Backus).

Relatively few observations of scattering layers were made during this quarter. One set of observations of good quality made with the 12 kc echo sounder in mid-January south from Woods Hole to the 1500 fathom curve show little or no development of scattering layers. It is difficult to interpret this isolated record. Records made from the R/V ATLANTIS in 1950 at the same location and at the same season using an explosive sound source show well developed layers.

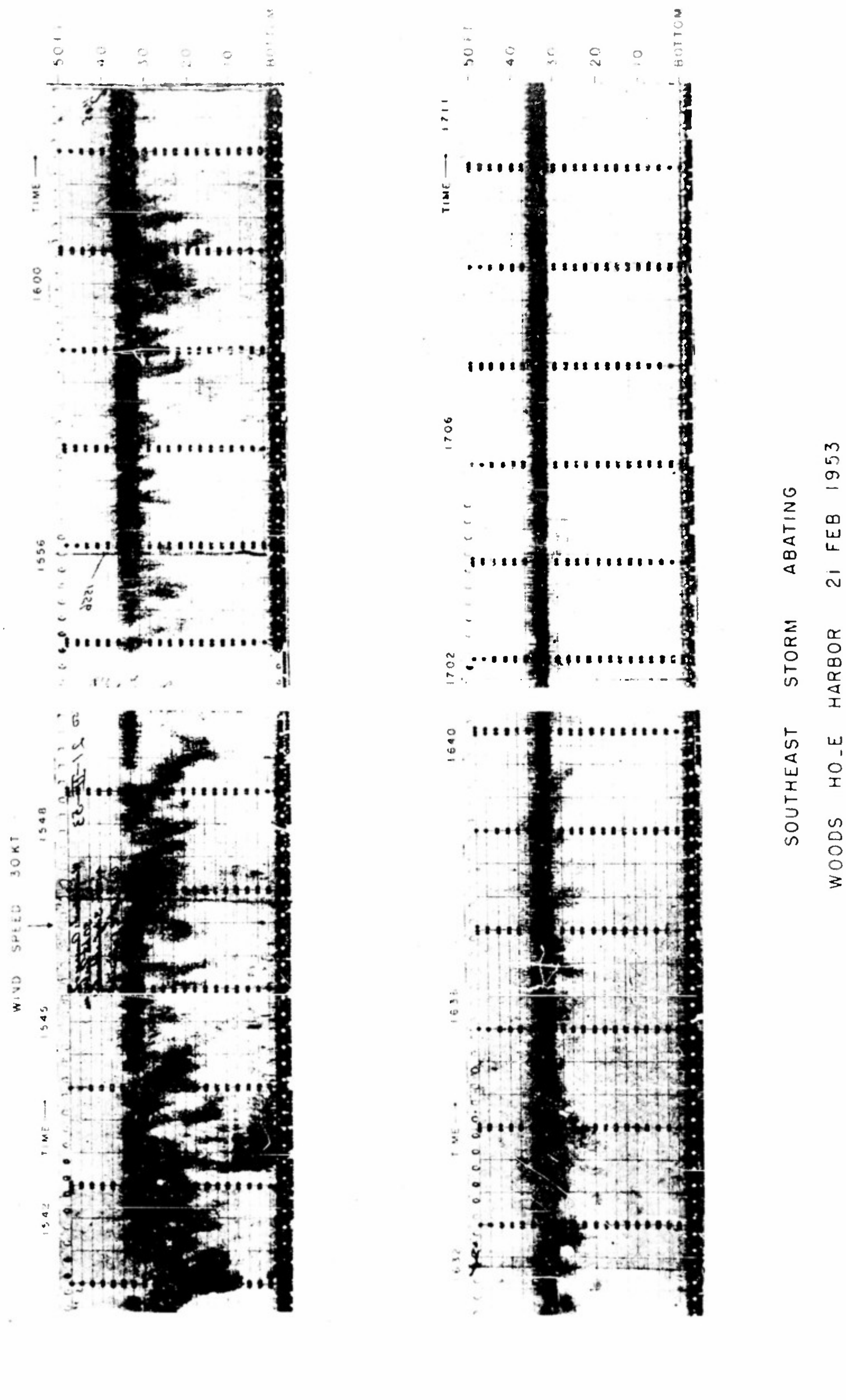

WIND SPEED 30KT
TIME
1542
1545
1548
1556
1600
1632
1636
1640
1702
1706
1711
50FT
40
30
20
10
BOTTOM
SOUTHEAST STORM ABATING
WOODS HO_E HARBOR 21 FEB 1953

FIG.8

Scattering Layer Analysis (Mr. Davis).

Analysis of scattering layer recordings from explosives (WHOI Ref. No. 51-80) have continued at rather low priority. Calculations of the directivity index for the ATLANTIS hull-mounted hydrophone have been made. (These indices were calculated from measurements made in July 1951.) An extensive analysis of recordings of the scattering layers of the open ocean is progressing as rapidly as time allows. The analysis is expected to give the back scattering coefficient as a function of frequency and depth. Many records in a few discrete frequency bands are available from cruises in other years, and a few magnetic tape recordings have been taken that can be analyzed to yield a continuous spectrum of the scattering.

BACKGROUND NOISE

Ambient Noise (Mr. Johnson).

With the cooperation of the Harbor Defense Unit at Deer Island, Massachusetts commanded by Lt. J. F. Cahill,(Officer-in-Charge,) continuous ambient noise records have been obtained over long periods of time. On January 16, 1953 two Esterline Angus ink recorders were installed at the Deer Island installation to be fed by two Mark 6 Mod 0 harbor defense listening systems with hydrophones in the Boston Harbor north channel area. The recorders were operated continuously from January 16th to February 20th when casualties to both systems prevented further recording. The Harbor Defense group tended the recorders during this period of time. Repairs have now been effected and on March 31st the recorders were back in operation. During the January 16 - February 20 period both recorders were fed by linear amplifiers. It was found that practically all passing ships overloaded the systems. The amplifier installed on March 31st consists of one logarithmic channel as well as a linear channel to enable recording of sound levels produced by shipping as well as the lower ambient noise levels when ships are not present. This amplifier is connected directly to the hydrophone lead-in cables rather than to the outputs of the Mark 6 Mod 0 amplifiers to eliminate the possibility of overload in the Mark 6 stack. Unfortunately the possibility of overload in the hydrophone preamplifiers still exists on very intense sounds.

Minimum background levels have been plotted as representive of broad band ambient noise levels during the period of time the recorders were operated. Minima were plotted because transient sounds such as clanking of navigation buoy chains were recorded as maxima. The record from January 16th to February 2nd has been plotted and correlated with weather data obtained from the logs of Boston lightship. It was found that the minimum background levels followed changes in wind force very well with a maximum increase of 8 db during a wind force 8 northeast storm over the levels obtained on days when the wind forces were 0 to 1. Knudsen et al. report an increase in over-all level of approximately 25 db between these two wind force conditions in Survey of Underwater Sound, Report No. 3, Ambient Noise, NDRC. This discrepency could be explained if it is found that the low wind force absolute levels are high at this location.

Absolute levels have not been determined due to lack of system calibrations. However, on February 4th simultaneous magnetic tape recordings were made on Deer Island and on the R/V CARYN of both ambient noise and two transmission runs by the R/V BEAR towing a Mark 4 (v) sound source. The runs are described in more detail by Dr. F. T. Dietz above. It is hoped that reference levels and frequency responses of the Deer Island systems can be determined by analyses of these records.

SUBMARINE GEOLOGY AND GEOPHYSICS

Submarine Geology in the Gulf of Mexico (Mr. Stetson et al.).

During this quarter the analysis of the long core samples from the western Gulf of Mexico was resumed, one hundred and thirty samples were run and the statistical constants calculated, bringing this phase of the Gulf investigation to near completion.

The first comprehensive report on the sediments of the western Gulf was completed and is now in page proof. This comprises a study of the texture and zoning of the surface sediments of the entire area of the shelf, slope and Sigsbee Deep, and a study by Trask of the organic carbon and nitrogen and other chemical properties of both the surface sediments and of the cores from the same area.

In cooperation with the Humble Oil Co. a preliminary study was made of the rock samples broken from the cliffs of the very extensive fault scarp which makes the seaward margin of the west Florida continental shelf. Mr. R. D. Woods has determined the foraminifera from thin sections of these samples. Any information concerning the seaward extension of the Coastal Plain formations is of importance not only from the stratigraphic point of view but also as it concerns the broader problem of the formation of continental terraces and subsiding continental margins. The only previous samples of this sort have been obtained from the submarine canyon walls on both the east and west coasts.

Dr. Shepard W. Lowman of Rensselaer Polytechnic Institute has agreed to study foraminifera from a part of the material collected by the ATLANTIS in the northwest Gulf during March 1951. Mechanical analyses of the 325 samples from cores taken by the ATLANTIS from the northwest Gulf of Mexico during March 1951 have been completed.

The problem of the behavior of unstable sediments underlying the continental shelf and slope in the northwest Gulf of Mexico has been studied. The principles of soil mechanics as determined by engineers has been applied with interesting results. A series of conferences have been held with Dr. S. D. Wilson of the Division of Applied Science at Harvard, and it has been found that although geologists and engineers have been working on the problem of the behavior of sediments under stress for many years, cooperative investigations by the two groups have been almost entirely lacking. Among the facts commonly known to engineers but almost unknown to geologists and which may be applied to the problem of the origin of the continental slope topography are: Normal sediments under certain stress conditions may flow as fluids; they may be strong one minute and liquid the next. Sediments may flow down slopes for relatively great distances without disturbing the vertical sequence of bedding in the transported mass; that is, the fact that a deposit is bedded is not proof that it has not been moved by landslide or sediment flow. Although clay may be relatively stable before failure, if it is moved or disturbed its strength may be greatly reduced and it may become unstable. In contrast to subaerial creep, submarine creep of sediments is not necessarily greatest near the surface; although sediments in general are weaker near the surface, stresses tending to produce failure increase with depth, so that sediments at certain depths may be more unstable than either those underlying or overlying them. It is possible that the sediments underlying the continental shelf and slope in the northwest Gulf of Mexico are constantly being moved down the slope by faults, landslides, sediment flows and turbidity currents. It is believed that much of the topography on the continental slope can be explained by these processes.

OCEANOGRAPHIC INSTRUMENTATION

Wave Instrumentation (Mr. C. O'D. Iselin, Dr. A. Wikstrom, Mr. Walden, Mr. Whitney and Mr. Holmes).

During the late summer and autumn a considerable number of possible systems for measuring open ocean waves had been suggested and in some cases partially tested by various members of our staff (see WHOI Refs. No. 53-41, pp. 5-6 and No. 52-101, pp. 11-13). Only gradually did it become clear how difficult it would be to devise a reasonably simple system that would produce a reliable record over a wide range of wave conditions. Discouraging results were encountered with a wave pole and damping disk combination as soon as measurements were attempted in vigorously breaking seas. Although a damping disk can be designed so that it rises somewhat more slowly than it descends, and thus compensates for the asymmetry of the wave profile, a system which is adjusted for moderate seas will gradually sink if the winds decrease or climb out of the water until the float broaches if the winds increase. The fact that in strong winds the surface water is moving down wind so much faster than the water at the level of the damping disk imposes further difficulty.

The upside down echo sounder has been used only enough to define some of the practical problems of operating it. Some of these are discussed separately above (pp. 10 and 11). In very shallow water where it is practical to mount the transducer on the bottom heavy winds have entrained so dense a mass of bubbles in the water as to mask the echo from the surface. This may or may not be a prevalent water condition in heavy storms even in shallow water since the observations were made in close proximity to the strong tidal current in Woods Hole. In open water the evidence from observations in three gales is that most of the time the bubbles entrained from the waves do not obscure the surface echo. However, there is a problem of depth control of the hovering mechanism on which the transducer is mounted. The period of depth fluctuation can be made very long compared with the period of the waves if the hovering mechanism is deep enough in relation to the longest waves being observed. This may well be practical with a small hovering device, and should be entirely feasible on such a platform as the deck of a submerged submarine.

While the significance of extremes in the environmental factors were being discovered by trial and error, Dr. Wikstrom and Mr. Walden rapidly developed electronic components that produce a wave record of excellent quality, provided a stable platform is available or the vertical movements of the system can be otherwise known and corrected for. There is now available a fully engineered system that records waves from an anchored wave pole. This will be useful for shallow water wave studies and as a means of calibrating free floating systems that are still in the stage of preliminary development. In principle their system has been used before, usually for measuring small waves in model studies. The change in capacitance of an insulated conductor that cuts the water surface is used to vary the frequency modulating a radio signal which can then be recorded in several standard ways. In short, this type of wave pole is at least a reasonably simple and versatile starting point. When tests which we are carrying out for DTMB, beginning in June, get underway there will be opportunity under another contract to compare in detail the power spectrum computed from the capacitance method with that obtained much more laboriously from simultaneous moving pictures of the rise and fall of the water surface along the pole.

Meanwhile, two additional possibilities are being investigated. Mr. Holmes and Mr. Bartels, during their tests of the British air-borne wave recorder (see below), became convinced that it was possible to design an unrestrained wave pole whose natural period of oscillation would be so much greater than the periods of the waves exciting it that very little overlap of frequencies would occur. This would certainly be true if the pole were sufficiently long and sufficiently heavy. Small scale tests were so promising that they have begun to assemble the electronic components that would fit into such a shaped float and would transmit the rise and fall of the water along the small diameter part of the float to the attending vessel.

There is no doubt that within practical dimensions such a system could be given a considerably longer natural period than that of the pitch of a reasonably sized ship. In other words, it should be easier in this system through an accelerometer to subtract the rise and fall of the long floating pole from the rise and fall of the water along the exposed portion than in the shipborn wave recorders under development and test in England and at Hydro. Here the accelerometer has to correct for the period of pitch of the vessel, namely in the 3 to 8 second range, while frequencies of the pole visualized by Mr. Holmes and Mr. Bartels should be negligible above about 0.1 second. Meanwhile, the possibilities of an accelerometer in a float are being investigated. Earlier in the study this combination had been dismissed as being too complicated and too direct, but at the present time no other system as yet suggested seems to have a clear advantage.

The British air-borne wave recorder was made operative during the winter months with the help of Mr. Bartels of Raytheon. It was flown several times locally in our PBY and then arrangements were made by Hydro to take it to the Caribbean where several long flights were carried out. A full report on the performance of this instrument is being prepared. Briefly, the situation is about as follows:

1. The requirement that the plane be flown at 125 ft. is not to the liking of pilots during peace time flying.

2. At higher elevations the echoes become weak and also the instrument begins to look at too large an area of the sea surface.

3. The electronic components are far from rugged. Very careful shock mountings are necessary for the instrument to survive landings and take-offs.

4. The antennae are large and awkward to mount.

5. The waves are recorded on a very narrow strip of paper. Consequently the instrument is constantly trying to center the record on the paper. Electrically it would have been much simpler and the record would be much more convincing if unavoidable departures from level flight had been fully recorded on a wide strip of paper. Except when very long swells are present there is little danger of confusing the two effects.

6. The instrument in its present form is judged to be marginal for the purposes of wave research. If the need arose, it would not be too difficult to design a more rugged and more powerful instrument of the same type using some of the components of standard U. S. radio altimeters. Such an instrument might be well suited to record large waves, but the dangers of flying low near the center of a severe storm should not be forgotten.

Deep Electronic Bathythermograph (Mr. Schleicher).

The first model of the electronic recording temperature meter was delivered to the Coast Guard for use in their spring ice patrol studies.

Mr. Schleicher is continuing work on an improved version of this instrument which is to be smaller and is also to measure and record the electrical conductivity of sea water. The first step in this program will be to make a breadboard model for test in the laboratory by the group who make titrations. It is hoped that this testing program will result in a more trouble-free field instrument.

ACOUSTIC INSTRUMENTATION

Hydrophones and Depth Meters (Mr. Knott, Mr. Witzell and Miss Bunce).

This quarter has been devoted entirely to the modification and completion of our planned inventory of cables and incorporated depth meters.

During this period all 250 foot, 500 foot and 1000 foot bourdons have been recompensated to their respective common deflections. This is part of a calibration procedure used to standardize the operation and future calibration of the depth meters and will be discussed in more detail in an engineering report now being prepared. The full complement of five 250 foot depth meters is compensated to a common calibration curve which holds on all four indicators. The five 500 foot bourdons are compensated to a common full scale deflection. These are not assembled in depth meter form because of modifications underway on the remaining inner cases. New cable should be available for these instruments by mid April. Of the five 1000 foot meters, 2 are assembled on cables, the rest are compensated and assembled in the modified inner bourdon cases.

Two modifications have been made to the depth meters. The first is the installation of large I.D. 1/8" stainless tubing on all bourdons which replaces the capillary inlet tube formerly supplied with the bourdons. This change allows a more rapid response to small increments of sea water depth and speeds up calibrations because oil is used for the hydraulic fluid in the dead weight tester. The second modification is a change in the inner case which makes available a quick mechanical zero setting without the necessity of a complete dismantling of the depth meter. This change is desirable because it simplifies the calibration of the depth meters to common curves. This also permits the electrical adjustments on the indicators to be locked and left untouched during operation, which reduces human error.

Two new depth indicators have been produced. These have two channels each with selector switches for choice of depth meter range and for sensitivity. Since all depth meters in a given range have equal sensitivity the three different sensitivities can be adjusted and locked. Then the operator merely sets the selector switch for the depth range desired and is not required to change variable resistors which would throw the instrument out of calibration.

Investigation is underway to locate and purchase a desirable type of hermetically sealed plug and sockets for use at cable terminations at the depth meters. The installation of the plugs in the cable lines will obviously restrict cable and instrument flooding to the section where the trouble is located. It is desired to find the type plug which would require the least modification to the present instruments.

A waterproof plug has been developed for our top side cable ends. This uses the same inserts as our present amplifiers require. (See figures 9 - 12.) They are sealed at the cable by neoprene hose and are sealed when not in use by a cap with an "O" ring gasket. The cap is chained to the cable. Previously plugs were taped when not in use for waterproof handling on deck; this was time consuming and not always effective. This same plug can be used effectively for underwater connections if mating parts are similarly designed.

Electronic Instrumentation (Mr. Dow et al.).

Development of new equipment was somewhat limited during this quarter by several factors. Firstly, the project technicians spent a large portion of this period at sea operating gear for various short cruises. Secondly, the temporary building in which development was being done had to be stripped of all the equipment in order that it might be moved to a new location. Following this the equipment was reinstalled, new water grounds put in, etc. As a result, design (on paper) of new and improved equipment far outstripped construction during this period. However, the following work was completed and the remaining construction is underway.

Amplifier-Drivers for Pen Recorders. The laboratory extensively uses a technique whereby data is recorded wide band at sea on magnetic tape. The tape is then played back in the laboratory through filters to direct writing recorders for analysis. It was found that the gain of the normal driver-amplifier was insufficient for this work, therefore additional gain has been built into these units. Pulse shaping circuits designed to give a fine line timing record, and limiters to protect the pens handling high amplitude transients on unrectified signals have also been incorporated. The alterations were made by Melville Edwards and Henry Cain.

Direction Finder. The limiter amplifier used as a portion of the direction finding equipment, and described in the previous quarterly

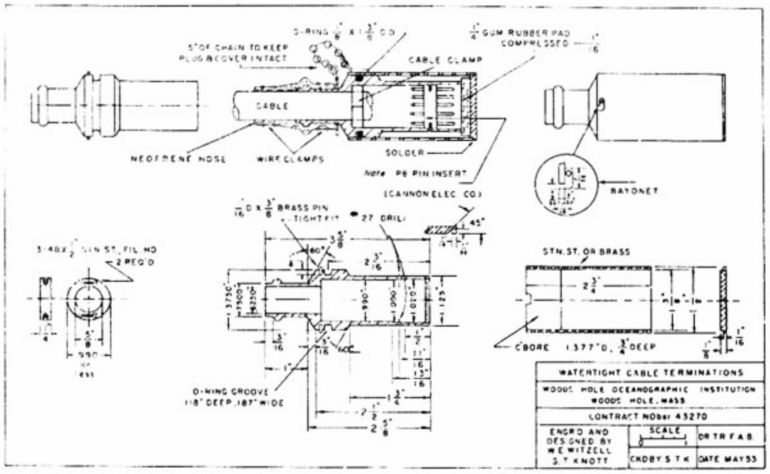


FIG. 9

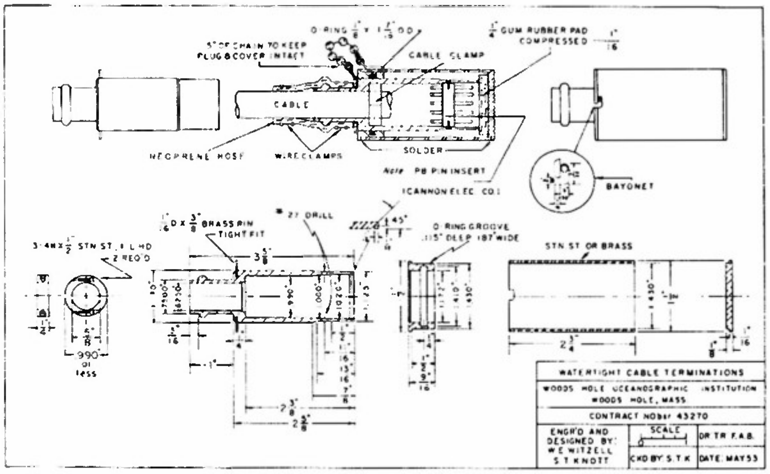


FIG. 10

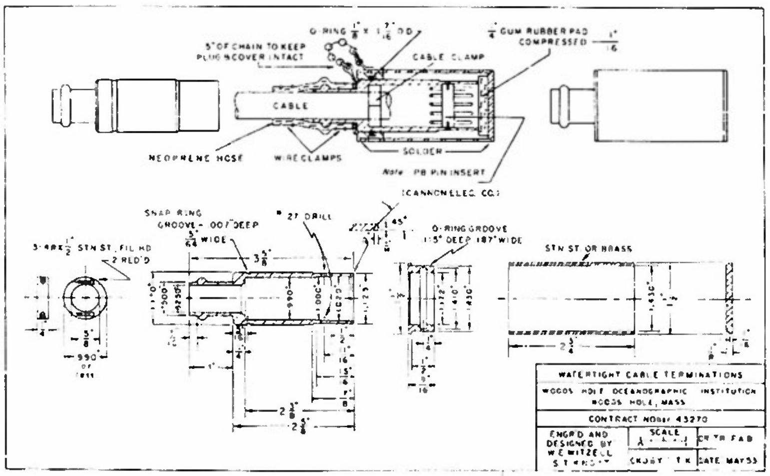
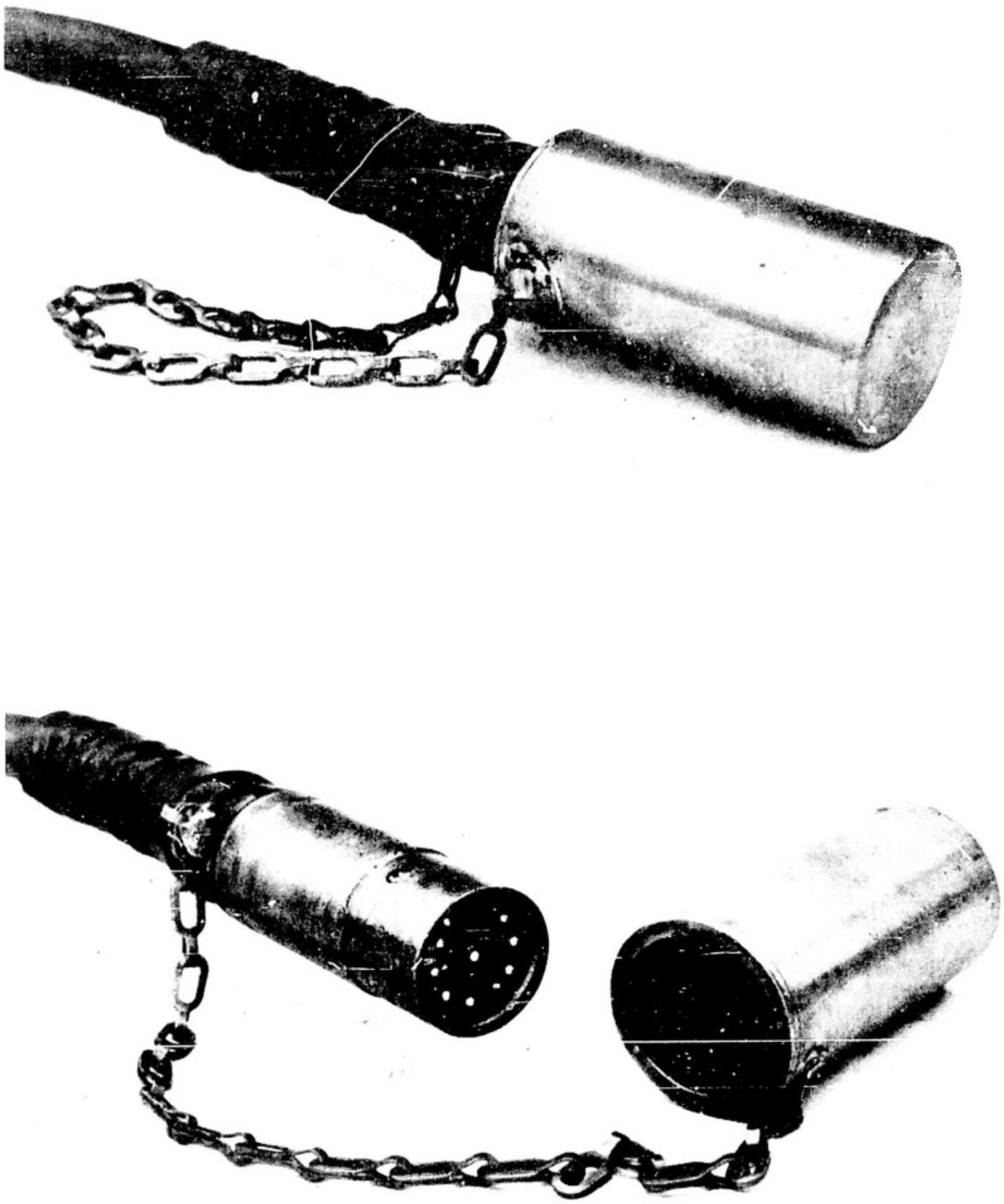


FIG. 11



WATERTIGHT CABLE TERMINATIONS

FIG. 12

report, has undergone further tests. Modifications in the phase bridge circuit were found desirable for our application and this work is underway.

Suitcase Amplifier. Several changes have been made in the suitcase amplifier to improve operation on high level signals such as those originating from explosives. These are as follows:

(1) An additional low loss calibration circuit (6 db loss) has been installed to permit electrical calibration to be made at a level approaching that generated by large signals at the hydrophone.

(2) The input stage has been changed from a pentode to a grounded grid triode, and the circuit rearranged to permit higher amplitude signals to be handled without distortion. The self noise of this stage was also considerably reduced by the change.

(3) The splicing switch whereby two channels may be operated from the same hydrophone has been moved to the input stage to permit greater flexibility in the operation of the spliced channel.

Power Supplies. Two power supplies for suitcase amplifiers were built by Henry Cain during this quarter.

Noise Generators. Considerable progress was made in the development of noise generators for calibration work during this period. Stability, both as to output voltage and frequency spectrum has been greatly improved. The meter and attenuator circuits have also been revised to advantage and the life span of the noise generating diode has been considerably increased by protective devices and circuitry. The entire unit has been made more compact. The revisions were incorporated in the equipment by Mr. Carter, who also assisted very materially in the design improvements.

Echo Ranging Set. The special echo ranging equipment mentioned in previous reports has been revised to permit greater reliability in the keying unit, better performance of the receiver on weak signals and more output power from the transmitter. Revisions were made by Messrs. Carter and Dow.

Range Recorder. The circuitry of the range recorder has been revised to provide greater reliability of long periods of continuous operation. A blanking circuit to remove the signal from the stylus on retrace has been incorporated in the driving amplifier by Mr. Edwards.

Bermuda Expedition. An expedition to Bermuda was made between February 22nd and March 4th during which explosive shots fired from a destroyer were recorded at the Sofar stations at High Point and St. Davids.

Equipment was revised and rigged for this operation at Woods Hole and then shipped to Bermuda. The work included rebuilding a commercial binaural recording amplifier to permit two channel operation, installation of calibrated attenuators, high level bridging circuits and revised circuitry to increase gain and improve signal-to-noise ratio. These alterations were made by Gerrit Duys.

Changes were also made in the preamplifier circuits on the Island to permit multi-level recording and wider dynamic range on the existing channels, so that nearby shots could be faithfully reproduced.

Telemetering Depth Meter. A self-contained depth meter which transmits depth information to the ship acoustically has been developed and has given excellent performance during several sea trials. However, the maximum depth available locally is only 100 feet, and the true value of the instrument will be determined by future trials in deeper water and under conditions of higher noise levels.

APPENDIX

Use of Vessels

Operations of the R/V ATLANTIS during the quarter were as follows:

Cruise #	Departure Return	# of Days of Voyage	Ports of Call	Scientist in Charge
	6 February	1	Woods Hole - Sea	J. B. Hersey
182	11 February 12 February	2	Woods Hole - Sea	J. B. Hersey
183	17 February 20 February	4	Woods Hole - Sea	J. B. Hersey
184	6 March 11 April	37	Woods Hole-Bermuda Guantanamo Bay Jamaica	A. C. Vine

Operations of the R/V CARYN:

56	15 January 17 January	3	Woods Hole - Sea	G. Duys, Jr.
57	23 January	1	Woods Hole - Sea	R. H. Backus
58	27 January	1	Woods Hole - Sea	F. T. Dietz
59	29 January	1	Woods Hole - Sea	F. T. Dietz
60	30 January	1	Woods Hole - Sea	J. B. Hersey
61	4 February	1	Boston Harbor	F. T. Dietz
62	17 February 20 February	4	Woods Hole - Sea	C. B. Officer

Cruise #	Departure Return	# of Days of Voyage	Ports of Call	Scientist in Charge
	Operations of the R/V BEAR:			
41	27 January	1	Woods Hole - Sea	S. W. Bergstrom
42	29 January	1	Woods Hole - Sea	S. W. Bergstrom
43	4 February	1	Boston Harbor	S. W. Bergstrom
45	18 March	1	Woods Hole - Sea	F. T. Dietz
47	24 March	1	Woods Hole - Sea	G. Duys, Jr.
48	26 March	1	Woods Hole - Sea	G. Duys, Jr.
49	27 March	1	Woods Hole - Sea	G. Duys, Jr.

Visitors List

Visitors during the quarter with whom certain phases of our sonar research program were discussed include the following:

Mr. R. E. Banks	Naval Research Establishment
Mr. J. C. Beckerle	Bell Telephone Laboratories
Mr. R. E. Blake	Naval Research Laboratory
Dr. E. T. Booth	Hudson Laboratories
Dr. G. H. Curl	U. S. Navy Electronics Laboratory
Dr. R. A. Frosch	Hudson Laboratories
Dr. J. W. Horton	U. S. Navy Underwater Sound Laboratory
Mr. J. S. Knauss	Office of Naval Research
Mr. J. R. Longard	Naval Research Establishment
Dr. H. W. Marsh, Jr.	U. S. Navy Underwater Sound Laboratory
Lt. Cdr. F. R. Mitchell	Submarine Development Group TWO
Mr. H. E. Nash	U. S. Navy Underwater Sound Laboratory
Mr. R. H. Nichols	Bell Telephone Laboratories
Mr. Aubrey Pryce	Naval Research Laboratory
Mr. M. Schulkin	U. S. Navy Underwater Sound Laboratory
Mr. R. J. Urick	Naval Research Laboratory
Cdr. E. M. Usherwood	British Joint Services Mission
Mr. R. A. Walker	Bell Telephone Laboratories
Dr. R. A. Westervelt	U. S. Navy Underwater Sound Laboratory
Sir Charles Wright	Marine Physical Laboratory

Personnel

Name	Title
J. B. Hersey	Physical Oceanographer
A. C. Vine	" "
W. E. Schevill	Research Associate in Physical Oceanography
W. Dow	Engineer
F. T. Dietz	Physicist
C. B. Officer, Jr.	"
Jane Roberg	"
J. S. Kanwisher	Bio-physicist
H. C. Stetson	Submarine Geologist
G. P. Woollard	Associate in Geophysics
R. H. Backus	Research Assoc. in Marine Biology
R. F. Wyrick	Research Assoc. in Underwater Acoustics
L. H. Barbour	Research Assist. in Oceanography
K. E. Schleicher	" " " "
G. H. Volkmann	" " " "
R. R. Brockhurst	Research Assoc. in Physics
Elizabeth T. Bunce	" " " "
Suzanne Brainerd	Research Assist. in Physics
L. C. Davis	" " " "
Priscilla K. Davis	" " " "
G. Duys, Jr.	" " " "
Jean McLeod	" " " "
S. W. Bergstrom	Research Assoc. in Engineering
J. F. Holmes	" " " "
H. R. Johnson	" " " "
S. T. Knott	" " " "
H. A. Cain	Research Assist. in Engineering
A. L. Carter	" " " "
M. E. Edwards	" " " "
W. E. Witzell	" " " "

Personnel (cont'd.)

Name	
R. A. Lufburrow	Research Assoc. in Mathematics
A. Bradshaw	Research Assist. in Mathematics
Barbara Atwood	Senior Technical Assistant
Betty Lee Gealy	" " "
Jean Stilwell	" " "
Barbara Bernache	Technical Assistant
Margery A. Brennan	" "
Marjorie A. Posgay	" "
Florence K. Mellor	Secretary
Betty P. Ostiguy	"
Margaret G. Meredith	Typist-clerk

Distribution List
Reference No. 53-46

Bell Telephone Laboratories
Murray Hill, New Jersey
Attn: C. F. Weibusch
Dept. 4500
Via: ONR, New York — 1 copy

Research Analysis Group
Brown University
Providence, Rhode Island
Via: ONR, Boston — 1 copy

Chief, Bureau of Ordnance
Department of the Navy
Washington 25, D. C.
Attn: Section Re2b
Via: InsMat, Boston — 1 copy

Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.
Attn: Code 847 — 2 copies
Code 814 — 4 copies
Code 108 — 1 copy
Via: InsMat, Boston

Chief of Naval Research
Department of the Navy
Washington 25, D. C.
Attn: Code 416 — 1 copy
Code 418 — 1 copy
Code 411 — 1 copy
Code 466 — 1 copy

Commander
Submarine Development Group TWO
c/o Fleet Post Office
New York, New York — 1 copy

Defense Research Laboratory
University of Texas
Austin, Texas
Attn: C. P. Boner — 1 copy
Via: Res. Rep. ONR
Univ. of Texas, Austin

Edo Corporation
College Point
Long Island, New York
Attn: Dr. C. E. Mongan
Via: BuAer Rep.,
College Point — 1 copy

Force ASW Officer
Commander, Submarine Pacific
c/o Fleet Post Office
San Francisco, California — 1 copy

Hudson Laboratories (Project Michael)
Dobbs Ferry, New York
Via: ONR, New York — 1 copy

Inspector of Naval Material
120 Tremont Street
Boston 7, Massachusetts — 1 copy

Director
Lamont Geological Observatory
Torrey Cliff
Palisades, New York
Via: ONR, New York — 1 copy

Director
Marine Physical Laboratory
University of California — 1 copy
San Diego 52, California
Via: USNEL, San Diego, Cal.

Acoustics Laboratory
Massachusetts Institute of Technology
Cambridge 39, Massachusetts
Via: InsMat, Boston — 1 copy

Naval Research Establishment
Halifax, Nova Scotia — 1 copy
Via: Canadian Joint Staff
Washington, D. C.

Naval War College
Newport, Rhode Island — 1 copy

Distribution List (Cont.)
Reference No. 53-46

Director
Scripps Institution of Oceanography
La Jolla, California 1 copy
Via: USNEL, San Diego, Cal.

Head
Department of Oceanography
Texas A & M
College Station, Texas 1 copy
Via: InsMat, Houston, Texas

University of Michigan
Ann Arbor, Michigan
Attn: Dr. J. Frederick 1 copy
Via: ONR, Ann Arbor

Librarian
U. S. Naval Postgraduate School
Monterey, California 1 copy

Director
U. S. Navy Electronics Laboratory
University of California
San Diego 52, California 1 copy

Hydrographer
U. S. Navy Hydrographic Office
Washington 25, D. C. 2 copies

Director
U. S. Navy Underwater Sound Laboratory
Fort Trumbull
New London, Connecticut 1 copy

Vitro Corporation of America
962 Wayne Avenue
Silver Spring, Maryland 1 copy
Via: Devl. Cont. Officer, Silver Spring, Md.

Professor L. W. McKeehan
Edwards Street Laboratory
Yale University 1 copy
New Haven, Connecticut
Via: ONR, New York

Development Contract Administrator
Ordnance Research Laboratory
Post Office Box 30 1 copy
State College, Pennsylvania

British Joint Services Mission
Navy Staff 3 copies
Washington, D. C.
Via: BuShips, Code 365

Director
University of Miami
Marine Laboratory
Coral Gables, Florida 1 copy
Via: InsMat, Atlanta, Georgia

Canadian Joint Staff
Washington, D. C.
Via: InsMat, Boston 4 copies

Director
Narragansett Marine Laboratory
University of Rhode Island
Kingston, Rhode Island 1 copy
Via: ONR, Boston

Office of Naval Research
Project Officer
U. S. Navy Sofar Station
APO 856 1 copy
c/o Postmaster, New York
Via: InsMat, Boston

Commander
U. S. Naval Ordnance Test Station
Pasadena Annex
3202 East Foothill Blvd. 1 copy
Pasadena 8, California
Attn: Library

U. S. Navy Research Laboratory
Washington, D. C.
Attn: Code 4000 1 copy
Code 4010 1 copy